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13. ABSTRACT *(Maximum 200 words)*
The research has developed a readout circuit design, microbolometer designs, fabricated the readout circuits utilizing the MOSIS foundry service, tested the readout circuits, integrated microbolometers onto the readout circuit and tested microbolometers fabricated on the readout circuits. The readout circuit was designed according to the MOSIS AMI 1.6 um low noise analog CMOS design rules. The readout circuits were designed using capacitive transimpedance amplifiers (CTIA) and constant current buffered direct injection (CCBDI) schemes. Microbolometers were designed to have a detectivity of 10 8 cmHz 1/2/W with a 200Hz cutoff and 10 9 cmHz1/2/W with a 30 Hz cutoff. This was accomplished with the substitution of only one diffferent mask during the microbolometer fabrication thereby varying the length of the electrode arms. The operational readout circuits were fabricated in a third job submission to MOSIS. The fabrication of microbolometers on the readout ciruit does not affect the electrical characteristics of the readout circuit indicating a post-CMOS compatible fabrication process. Test bolometers fabricated on a readout circuit were tested and have displayed responsivity.

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Final Report

Semiconducting YBaCuO Uncooled Focal Plane Arrays

Award No. F49620-03-1-0042

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1. Objectives

Uncooled infrared detection has attracted considerable attention in recent years due to its potential to provide high quality infrared imaging with reduced cost, weight, and system size. This research project will investigate the fabrication and integration of low thermal mass, self-supporting YBaCuO microbolometers with a CMOS readout circuit to produce two-dimensional focal plane arrays. Low thermal mass microbolometers can provide a faster thermal time constant for the same degree of thermal isolation. This provides the potential for faster frame rate imaging that is advantageous in a variety of applications where the camera or objects in the scene are in motion. Alternatively, the lower thermal mass can be used to achieve increased thermal isolation while maintaining the same thermal time constant and frame rate. The increased thermal isolation can be translated into higher responsivity and sensitivity. The performance of microbolometer imaging arrays is also determined by the interface and properties of the readout circuit. This research will investigate the integration of low thermal; mass microbolometers with a CMOS readout circuit that will be designed to interface with the YBaCuO microbolometers. The thermal isolation of the microbolometers will be varied by designing two different electrode arm geometries. One geometry will be design to obtain the goal of a relatively fast 200 Hz frame rate while maintaining a detectivity of 10^8 cmHz$^{1/2}$/W. The second electrode arm geometry will be designed to maximize the responsivity while maintaining a traditional 30 Hz frame rate. The goal is to achieve a detectivity of 10^9 cmHz$^{1/2}$/W. The research will help improve the performance of uncooled infrared cameras by the investigation of higher frame rate imaging and improvements in microbolometer sensitivity while simultaneously investigating the important issue of integration with a CMOS readout integrated circuit.

The readout circuit will be designed using the computer-aided engineering facilities of the Electrical Engineering Dept. at the University of Texas at Arlington. The CMOS readout circuit will be fabricated using the MOSIS foundry service. The microbolometers will be fabricated on the readout die using the NanoFab Center at the University of Texas at Arlington. The photolithography masks for the microbolometer fabrication will be designed at UTA and the masks will be fabricated at the Cornell Nanofabrication Facility. The resulting devices will be characterized in the Microsensor Laboratory at UTA. A comprehensive investigation of the noise, electrical, and optical characteristics of the focal plane arrays and test structures will be performed.

2. Status of the Effort (200 Words)

The goal of the research project is to investigate the integration of semiconducting Y-Ba-Cu-O microbolometers with a readout integrated circuit fabricated using the MOSIS foundry service. Work is progressing towards this goal. Four readout configurations were designed using capacitive transimpedance amplifiers (CTIA) and constant current buffered direct injection (CCBDI) schemes. The readout circuit has been designed and largely successfully fabricated using the MOSIS foundry service. Microbolometers have been designed with two thermal time constants to permit responses at 30 Hz and 200 Hz respectively. Microbolometers have been fabricated on the readout circuit die. Test transistors and test circuits show electrical characteristics close to those expected through circuit simulation. A CMOS substrate compatible fabrication process for the microbolometers has been developed. CMOS test devices show similar characteristics before and after the fabrication of the microbolometers on the CMOS substrates. This demonstrates Y-Ba-Cu-O microbolometers can be successfully integrated with CMOS readout circuitry. Microfabrication of the bolometers on a single readout die is

challenging. The CMOS readout circuit has not been planarized. This combined with the formation of the sacrificial polyimide mesas makes lithographic patterning a challenge. Device features have been successfully patterned using a combination of sputter deposition and lift-off patterning. The threshold voltages and the current constants of the fabricated die correspond relatively closely to the parameters used in the design. Several problems were encountered with using MOSIS. These problems were remedied with the third readout circuit fabrication.

3. Accomplishments/New Findings

The research has developed a readout circuit design, microbolometer designs, fabricated the readout circuits utilizing the MOSIS foundry service, tested the readout circuits, integrated microbolometers onto the readout circuit and tested microbolometers fabricated on the readout circuits. The readout circuit was designed according to the MOSIS AMI 1.6 μm low noise analog CMOS design rules. The readout circuits were designed using capacitive transimpedance amplifiers (CTIA) and constant current buffered direct injection (CCBDI) schemes. Microbolometers were designed to have a detectivity of 10^8 cmHz$^{1/2}$/W with a 200 Hz cutoff and 10^9 cmHz$^{1/2}$/W with a 30 Hz cutoff. This was accomplished with the substitution of only one different mask during the microbolometer fabrication thereby varying the length of the electrode arms. The operational readout circuits were fabricated in a third job submission to MOSIS. The fabrication of microbolometers on the readout circuit does not affect the electrical characteristics of the readout circuit indicating a post-CMOS compatible fabrication process. Test bolometers fabricated on a readout circuit were tested and have displayed responsivity of

3.1 Tasks

Task #1 Design Readout Circuit

A readout circuit will be designed that includes multiplexing circuitry to address the microbolometer array, transimpedance amplifiers to integrate the current flowing through the microbolometer and preamplifier. The readout circuit will be fabricated at a commercial foundry such as MOSIS using a low noise analog CMOS technology. Nominally the readout would be for a 64x32 pixel array with a 50-micron pitch to maintain a relatively low foundry cost.

This task is completed. The largest array design was a 32x32 with a 65-micron pitch. Three circuits based on capacitive transimpedance amplifiers were design and one readout based on constant current buffered direct injection was designed.

Task #2 Microbolometer Design

Microbolometers will be designed to interface with the readout circuit. The electrode arm mask will be varied to achieve two different goals in detector design. One design will utilize a moderately low thermal conductance and the low thermal mass of the self-supporting geometry to obtain a relatively fast thermal detector, thermal time constant τ_{th}< 1 msec, while maintaining a detectivity D* ~ 10^8 cmHz$^{1/2}$/W. The second electrode microbolometer design will be aimed at maximizing the detectivity while maintaining approximately a 5 msec thermal time constant. The use of a thin metal film absorber to increase the absorption will be investigated as a trade off with the increase in thermal mass. The masks for the microbolometers will be fabricated at either the Cornell Nanofabrication Facility or a commercial facility.

This task has been completed. Two microbolometer designs have been implemented. One design is intended to provide a detectivity D* ~ 10^8 cmHz$^{1/2}$/W with a modulation rate of 200 Hz, while the other is designed to achieved a detectivity of ~ 10^9 cmHz$^{1/2}$/W with a modulation frequency of 30 Hz. The two different designs are accomplished by varying the length of the supporting thereby changing the thermal conductance from the bolometer to the substrate. The high detectivity design will require the implementation of an additional

absorber. A thin metal film absorber is planned to increase the absorption of the microbolometer and provide higher responsivity.

Task #3 Readout IC Fabrication

The CMOS readout IC's will be fabricated at MOSIS or a similar foundry using a low noise analog technology such as the AMI 1.5 micron process, which provides 15 die at $4,400 cost. The turn around time is approximately 8-10 weeks. Three runs have been budgeted to allow for iteration in the design.

This task has been completed. It required 3 fabrication runs to obtain functional readout circuits.

Task#4 Integration of Microbolometers with Readout IC

The read-out circuit die received from the Si foundry will serve as the substrates for the fabrication of the microbolometer arrays. The 2-D microbolometer arrays will be fabricated on top of the readout circuit using a polyimide sacrificial layer. The microbolometer integration will be performed at the NanoFab Center at the University of Texas at Arlington, which contains comprehensive fabrication facilities.

We have fabricated some microbolometer arrays on the readout circuits, though this task is still on going. Test microbolometers on the CMOS substrate have been characterized. The integration process has demonstrated that the electrical characteristics of the CMOS readout circuits are not changed through microbolometer fabrication. This demonstrates that the microbolometer fabrication process is CMOS compatible. It is challenging to fabricate the microbolometers on a single die. The use of polyimide sacrificial mesas presents some challenges to lithography on two different levels of the die. Functional microbolometers are obtained on the readout circuits.

Task#5 Focal plane array test

The resulting focal plane arrays will be tested for their detectivity and responsivity characteristics as a function of optical modulation frequency and frame rate. Extensive noise characterization of the readout circuits and microbolometers will be performed.

Test microbolometers have been characterized on the readout circuits. A 295 K temperature coefficient of resistance of –2.8 %/K was measured. The bolometer pixel resistance had a batch-to-batch variation ranging from 20 kΩ to 20 MΩ with most bolometers having a resistance of 3 – 4 MΩ. The bolometers showed a responsivity of approximately 250 V/W.

3.1 MICROBOLOMETER FABRICATION ON READOUT CIRCUIT

The microbolometers were fabricated on top of the readout circuit using the following procedure. All the layers were deposited by rf magnetron sputtering and patterned by conventional photolithography and lift-off except for the polyimide sacrificial layer, which was spin, coated. The microbolometer fabrication started by bonding the readout circuit die to a 4-inch carrier wafer with HD Microsystems PI-2555. Next the 400-nm-thick aluminum mirror layer was deposited and patterned. (Fig. 1, 2, 3)

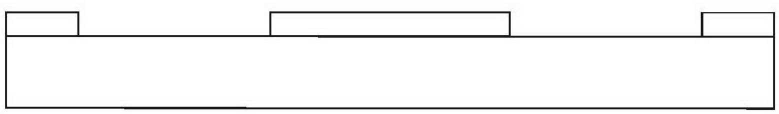

Fig. 1: Cross-sectional view of patterned aluminum mirror.

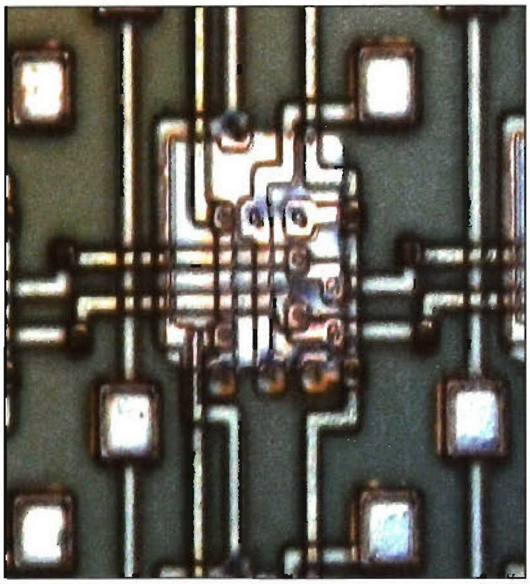

Fig. 2: Aluminum mirror and pads in a pixel on the 32x32 array.

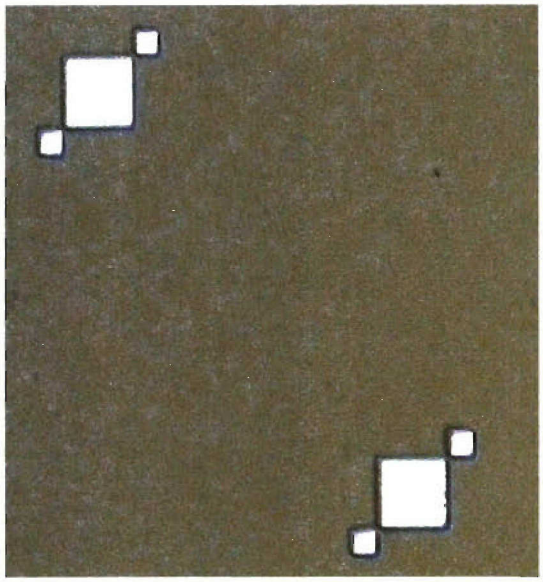

Fig. 3: Aluminum mirror and pads in a pixel forming a test bolometer.

The HD Microsystems PI2737 sacrificial layer was then deposited by spin coating was the deposited by spin coating, patterned by negative lithography, and cured at 275°C for 4 hours. The measured thickness of the polyimide mesas was ~1.95 μm to 2.2 μm. (Fig. 4, 5,6)

Fig. 4: Patterning PI-2737 to form MESA bridge.

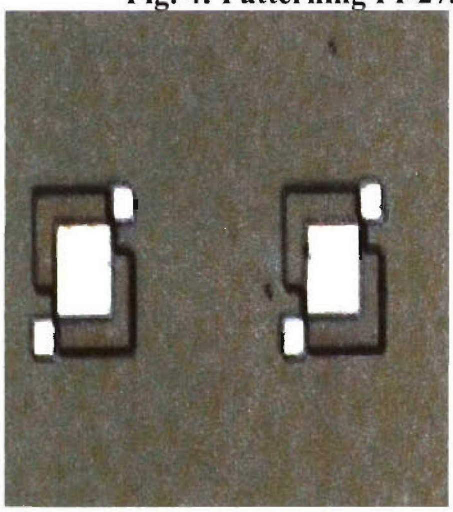

Fig. 5: PI-2737 mesas on test bolometer.

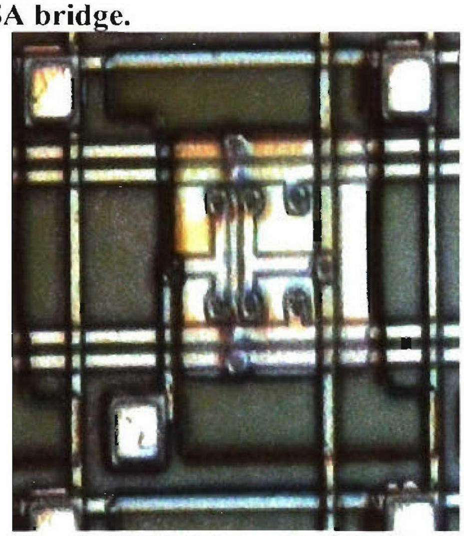

Fig. 6: PI-2737 mesa in 32x32 array.

The titanium electrode arms were then deposited and patterned. (Fig. 7)

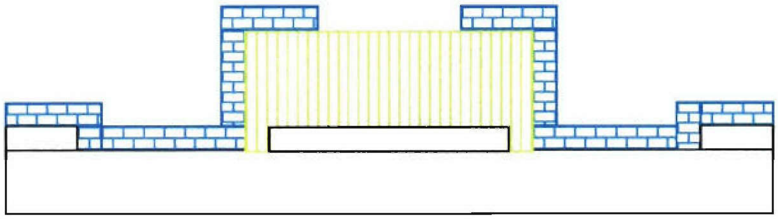

Fig. 7: Cross-sectional view showing the titanium electrode arms.

The gold contacts were deposited and patterned to provide a good contact to the YBaCuO thermometer. (Fig. 8, 9)

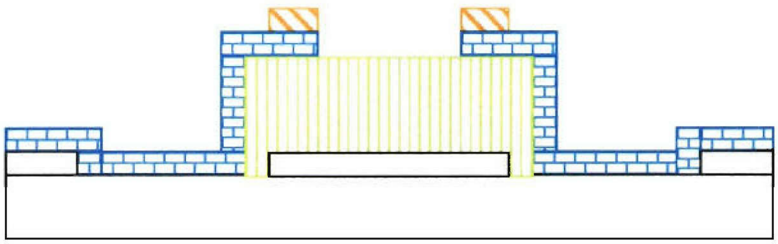

Fig. 8: Cross-sectional view of small gold contacts.

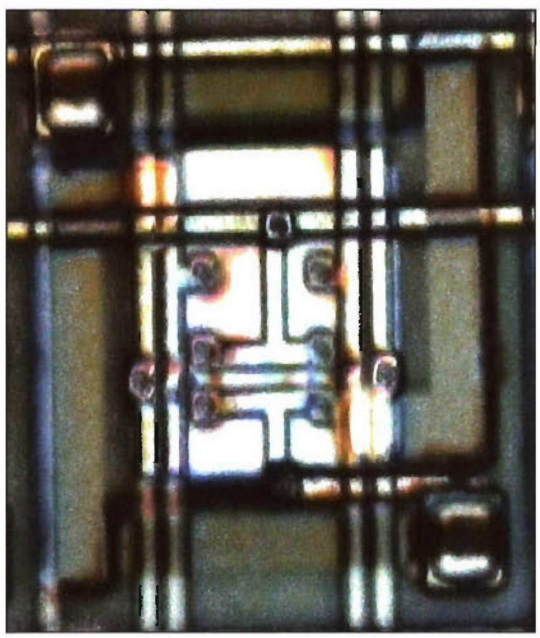

Fig. 9: Small gold contacts on a pixel in the 32x32 array.

The 400-nm-thick semiconducting yttrium barium copper oxide, referred to as YBaCuO, thermometer was then deposited and patterned on top of the polyimide mesa. (Fig. 10, 11) The Y-Ba-Cu-O in Fig. 29 and 30 appears rough because the readout circuit is not planar and the sputter deposited is conformal, following the topological features of the die.

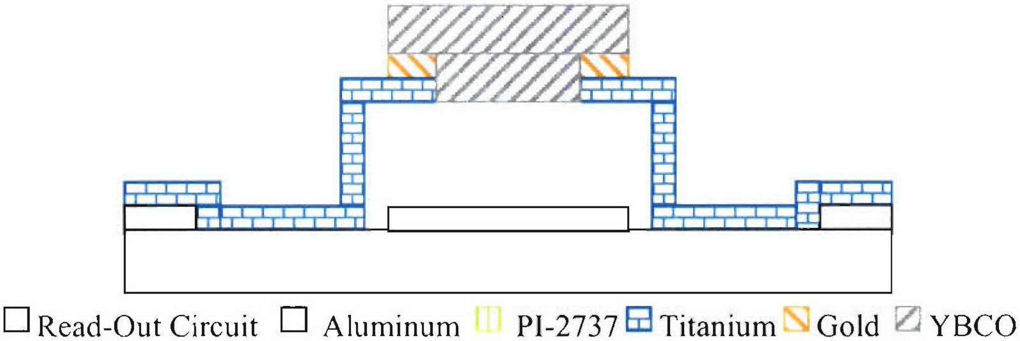

Fig. 10: Cross-sectional view of patterned YBaCuO after PI-2737 ashing.

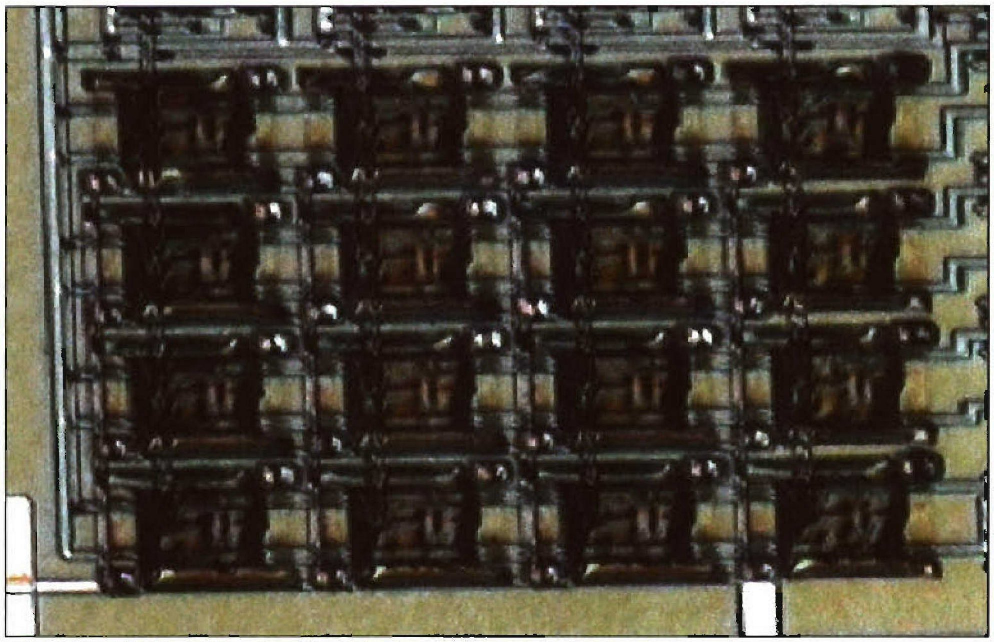

Fig. 11: Y-Ba-Cu-O microbolometers on 4x4 array.

The microbolometer fabrication was completed by ashing the polyimide sacrificial layer for 8 to10 hours. Scanning electron microscopy as shown in Fig. 12 inspected the completed microbolometers.

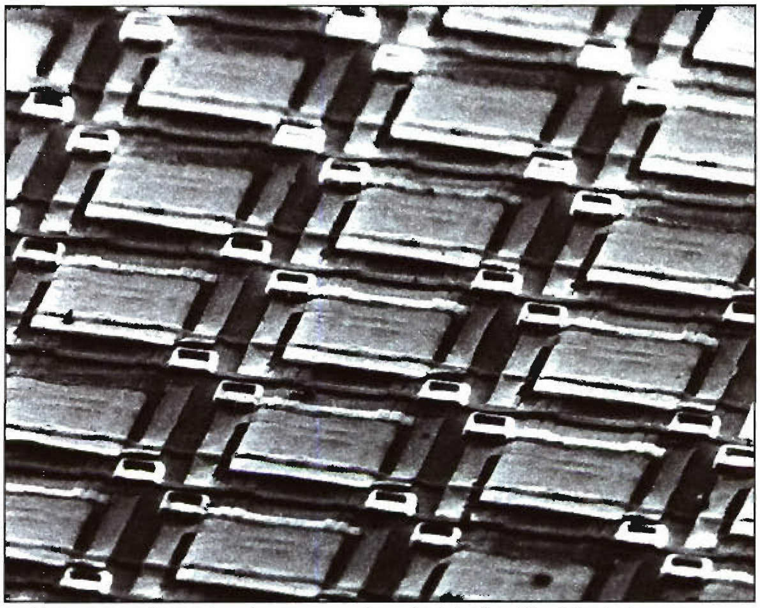

Fig. 12: SEM micrograph of ROC_II_32x32 array.

3.2 DEMONSTRATION of CMOS COMPATIBILITY of the MICROBOLOMETER FABRICATION PROCESS

To investigate the process compatibility of the microbolometer fabrication process with the CMOS readout circuit, the test transistors (Fig. 13), inverter, and CTIA amplifier were characterized on one die after fabrication and another die before microbolometer fabrication. The characteristics of 3 devices were measured in each case. The following graph compares the representative device performance before and after fabrication.

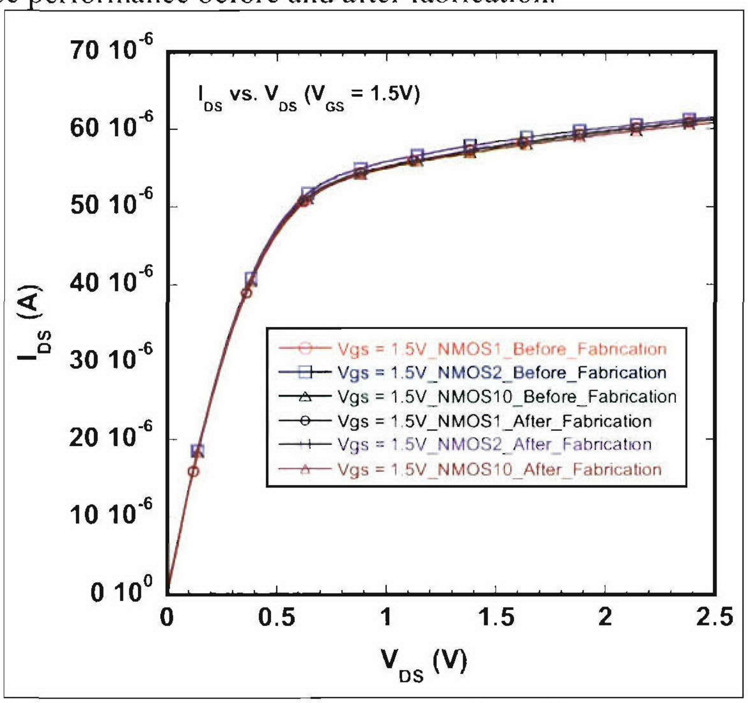

Fig. 13 NMOS drain current versus the drain-source voltage for a gate-source voltage of 1.5 V. Three NMOS transistors were tested before and after microbolometer fabrication.

The drain to source current versus drain-source voltage characteristics (Fig. 13) are a measure of both the threshold voltage and the channel mobility since in the saturation region the drain current varies as $I_D = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{gs} - V_T)^2$ where μ_n is the n-channel mobility, V_T is the threshold voltage, C_{ox} is the gate capacitance per unit area, W is the channel width, and L is the channel length. The NMOS and PMOS test transistors show very little variation from the die tested before microbolometer fabrication and after microbolometer fabrication. The PMOS transistors showed the greatest variation. This result also shows the foundry has very little variation in their transistors from die to die. The switching characteristics of the CMOS inverter also show little variation between the inverter tested before microbolometer fabrication and the inverter tested after microbolometer fabrication. The switching characteristic is asymmetric between the pull-up and pull-down because the p- and n-channel transistors had the same area. The asymmetry reflects the difference in the p- and n-channel mobility. Before microbolometer fabrication the ratio of the risetime-to-falltime was $\frac{tr}{tf} = 3.25$ where tr is the rise time and tf is the fall time, while after microbolometer fabrication the ratio is $\frac{tr}{tf} = 3.14$. The ratios are similar. The dc transfer characteristic of the CTIA amplifier was also measured before microbolometer fabrication and after microbolometer fabrication and the transfer characteristics are very similar.

3.3 MICROBOLOMETER CHARACTERIZATION

The microbolometers were characterized by measuring their resistance versus temperature characteristic in a closed cycle refrigerator to calculate the TCR (Fig. 14). The room temperature TCR was found to be approximately –2.8 %/K. The thermal conductance of the thermal isolation structure was measured by Joule heating and found to be 10^{-7} W/K.

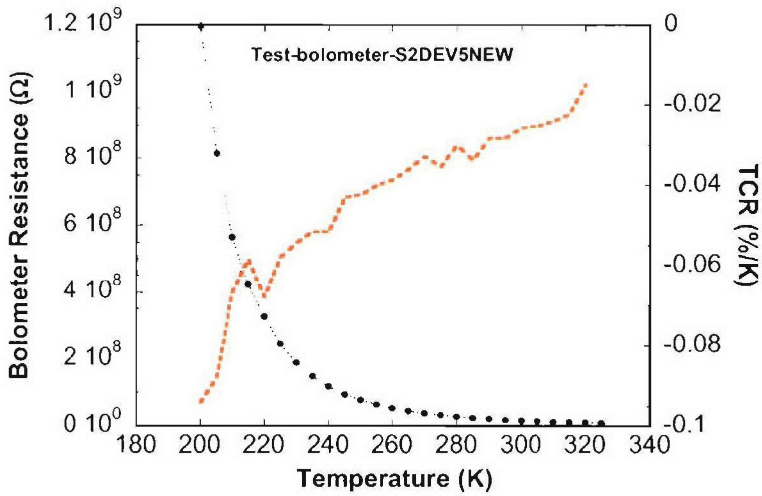

Fig. 14 Resistance versus temperature and TCR plot of test bolometer of resistance 20M ohms

Plotting an Arrhenius relationship for the resistance versus temperature shows a linear relationship (Fig. 15) with activation energy of 0.22 eV.

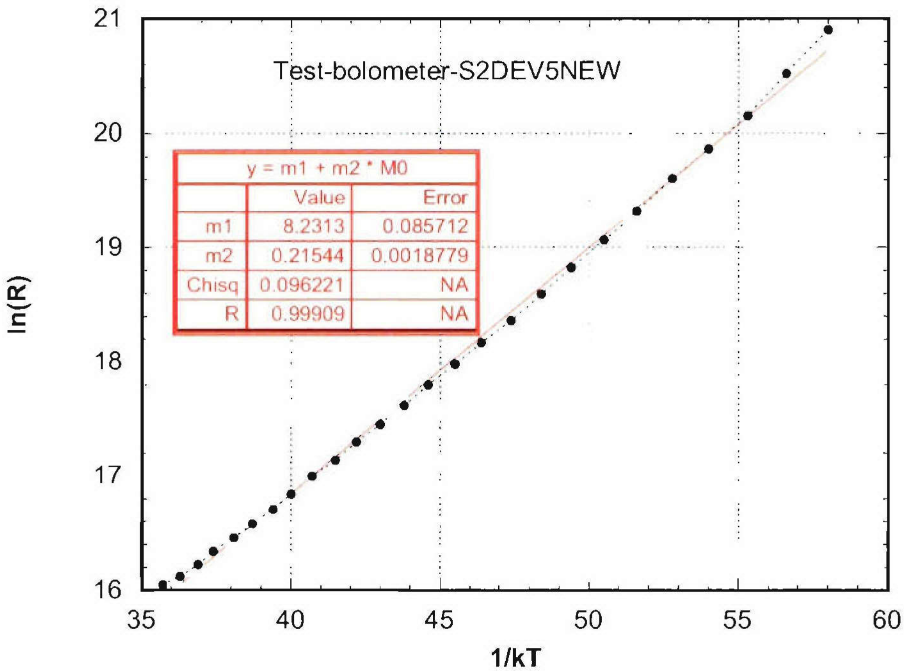

Fig. 15 Arrhenius plot of the resistance versus temperature of a test bolometer of resistance 20M ohms at room temperature

The responsivity of the microbolometer was measured using an infrared blackbody with a temperature of 900 °C. The microbolometer was mounted in an evacuated cryostat with a ZnSe window. A chopper was used to modulate the radiation. The electrical signal was amplified with a preamplifier before measuring it with an HP 3562A dynamic signal analyzer. The 16.6 MΩ bolometer was biased with 17.1V from batteries and a 15.3MΩ series resistor. The response was calibrated versus a calibrated Oriel pyroelectric detector. The responsivity versus chopper frequency is plotted in Fig. 16.

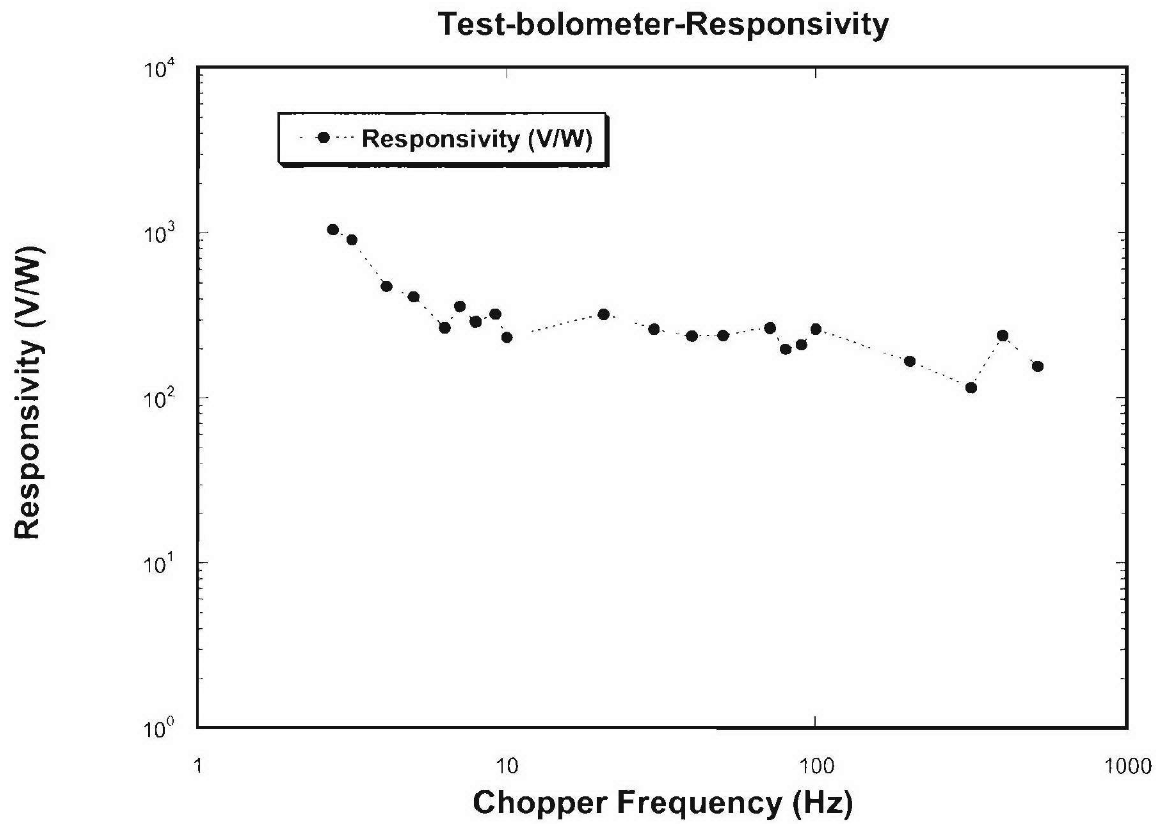

Fig. 16 Responsivity versus chopper frequency of a 16.6 MΩ test bolometer in vacuum with 550nA of biasing current.

3.3 Conclusion

Four different readout circuits were designed, three based on capacitive transimpedance amplifiers (CTIA) and one readout circuit based on constant current buffered direct injection (CCBDI). The readout circuits were successfully fabricated using the MOSIS foundry service. Problems with the MOSIS foundry were resolved in the third fabrication run. Microbolometers were designed to operate a modulation of 200 Hz and 30 Hz by varying the length of the electrode arm. The microbolometers were fabricated on the readout die using a polyimide sacrificial layer. The metal films and the Y-Ba-Cu-O were deposited by rf magnetron sputtering and patterned by liftoff. The highest temperature employed was the 300-°C cure of the polyimide sacrificial layer. The electrical characteristics of the circuits on the readout die were similar before and after the microbolometer fabrication process demonstrating process compatibility for the post-CMOS microbolometer fabrication. The microbolometer fabrication may benefit from the utilization of a post geometry for the electrode arm, rather than the current mesa geometry.

This project would benefit from continued support for a one-year period. An additional year of support would permit us to use the lessons learned from dealing with MOSIS to fabricate readout die with greater functionality. The post geometry could be adapted for the

microbolometer fabrication. In addition, we are working on another program that is investigating Si_xGe_{1-x} and $Si_xGe_{1-x}O_y$ microbolometers, which have similar pixel resistances and utilize a similar fabrication process. It would be interesting to investigate their integration with a readout circuit in addition to Y-Ba-Cu-O.

4. Personnel Supported

Professors Donald Butler and Zeynep Celik-Butler are professors in the electrical engineering department and co-principal investigators of the grant. Murali Chitteboyina is a Ph.D. student who entered into the Ph.D. program in electrical engineering at UTA in January 2003. Sandeep Kumar is a Ph.D. student who started in the Ph.D. program in electrical engineering in August 2003. Both Mr. Chitteboyina and Mr. Kumar were supported and research assistants under this grant. The PI has used student support that was part of his start-up package with UTA to provide support for Mr. Chitteboyina and partial support for Mr. Kumar during periods of this grant.

5. Publications

Conference Papers resulting from this research

1. "CMOS Readout Circuit for Semiconducting YBaCuO Microbolometers," Murali Chitteboyina, Sandeep Kumar, Donald P. Butler, 2004 TEXMEMS, College Station, Texas, Sept. 9th, 2004.

Other publications resulting from related research sponsored by other agencies

1. "Microbolometers on a Flexible Substrate for Infrared Detection," A. Yildiz, Z. Çelik-Butler, and D.P. Butler, IEEE Sensors Journal **4**, pp. 112-117 (2004).

2. "Flexible microbolometers promise smart fabrics with embedded sensors," A. Mahmood, D. Butler, and Z. Celik-Butler, Laser Focus World **40**, pp.99-103 April 2004. (invited)

3. Shadi A. Dayeh, Donald P. Butler, and Zeynep Celik-Butler, "Micromachined infrared bolometers on flexible polyimide substrates," Sensors and Actuators A **118**, pp. 49-56 (2005). Erratum: Sensors and Actuators A **125**, pp. 597-598 (2006).

4. Mukti M. Rana and Donald P. Butler, "RF Sputtered Si_xGe_{1-x} and $Si_xGe_{1-x}O_y$ Thin Films For Uncooled Infrared Detectors," accepted for publication in Thin Solid Films.

5. Aamer Mahmood, Donald P. Butler, and Zeynep Celik-Butler, "Micromachined bolometers on polyimide," accepted for publication in Sensors and Actuators.

2. "Uncooled micromachined bolometer arrays on flexible substrates," Z. Celik-Butler, D. P. Butler, S. A. Dayeh, and P. Wisian-Neilson, presented at the SPIE Aerosense, Infrared Technology and Applications XXVIX, Orlando, FL, April 2003. SPIE **5074**, pp. 537-547 (2003), B.F. Andersen and G.F. Fulop Editors.

3. "Micromachined Infrared Sensor Arrays on Flexible Polyimide Substrates," Aamer Mahmood, Shadi Dayeh, Donald P. Butler, and Zeynep Çelik-Butler, 2003 ETTC, Richardson, TX, 26,27 Sept. 2003.

4. Aamer Mahmood, Shadi A. Dayeh, Donald P. Butler, and Zeynep Celik-Butler, "Micromachined Infrared Sensor Arrays on Flexible Polyimide Substrates," presented at 2003 IEEE Sensors Conference, Toronto, Canada, 22-24 Oct. 2003.

5. Aasutosh Dave, Aamer Mahmood, Zeynep Celik-Butler, and Donald P. Butler, "Wafer Level self-Packaged Infrared Microsensors," presented at the SPIE 2004 Defense and Security Symposium: Infrared Technology and Applications XXX, Orlando, FL, April 2004.

6. "RF Sputtered Si_xGe_{1-x} and $Si_xGe_{1-x}O_y$ Thin Films For Microsensor Applications," Mukti M. Rana and Donald P. Butler, 2004 IEEE Emerging Technologies Conference, Richardson, Texas, Oct. 8^{th}, 9^{th}, 2004.

7. "Self-Packaged Infrared Microsensors," A. Dave, A. Mahmood, Z. Çelik-Butler and D. P. Butler, SPIE Defense and Security Symposium; Infrared Technology and Applications XXX, Orlando, FL, 28 Mar. - 1 April, 2005.

8. "Amorphous Ge_xSi_{1-x} and $Ge_xSi_{1-x}O_y$ thin films for uncooled infrared microbolometers," Mukti Rana and Donald P. Butler, SPIE Defense and Security Symposium; Infrared Technology and Applications XXX, Orlando, FL, 28 Mar. – 1 April, 2005.

9. "Device-level vacuum packaged micromachined infrared detectors on flexible substrates," Aamer Mahmood, Donald P. Butler, and Zeynep Celik-Butler, Presented at the IEEE Sensors Conference, Oct. 31 – Nov. 3 2005, Irvine, CA.

10. "Micromachined Infrared Microsensors on a Flexible Substrate," Shadi A. Dayeh, Zeynep Çelik-Butler and Donald P. Butler, TEXMEMS V, Fort Worth, Texas, May 6^{th}, 2003.

11. "Surface micromachined microbolometers on polyimide substrates," Aamer Mahmood, Donald P. Butler, and Zeynep Celik-Butler, TEXMEMS V, Fort Worth, Texas, May 6^{th}, 2003.

12. "Integrated Pressure and Infrared Sensors on Flexible Substrates for Smart Skin Applications," Sharmita Das, Vinayak Shamanna, Zeynep Çelik-Butler and Donald P. Butler, 2004 TEXMEMS, College Station, Texas, Sept. 9^{th}, 2004.

13. "Surface Micromachined Infrared Microsensors with Wafer-Level Encapsulation," Aasutosh Dave, Zeynep Çelik-Butler and Donald P. Butler, 2004 TEXMEMS, College Station, Texas, Sept. 9^{th}, 2004.

14. "Device level vacuum packaged micromachined microbolometers on flexible substrates," Aamer Mahmood, Donald P. Butler, and Zeynep Celik-Butler, 2004 TEXMEMS, College Station, Texas, Sept. 9^{th}, 2004.

15. "Si_xGe_{1-x} and $Si_xGe_{1-x}O_y$ Thin Films for Microbolometer Applications," Mukti M. Rana and Donald P. Butler, 2004 TEXMEMS, College Station, Texas, Sept. 9^{th}, 2004.

6. Consultative and Advisory Functions

-none

7. Interactions/Transitions

a. Participation/presentations at meetings, conferences, seminars, etc.

Donald Butler

2003-present, Topical editor for Applied Optics, Optical Society of America
1998- 2006, Webmaster for the IEEE Dallas Section
2000-2005 IEEE-Electron Devices Society Distinguished Lecturer
2000-present IEEE Electron Device Society Regions and Chapters Committee

Zeynep Celik-Butler

Editorial Activities, Conference Organization

1. Editor, Fluctuation and Noise Letters, World Scientific Publishing Company
2. Symposium Co-Chair, Session Chair, "Welcome" Speech, SPIE Symp. Fluctuations and Noise (FaN'2005) Austin, TX, May 23 - 27, 2005.
3. Conference Co-Chair, Smart Electronics, MEMS, BioMEMS, and Nanotechnology, SPIE Smart Structures and Materials, San Diego, CA, March, 2005.
4. Member, International Advisory Committee, International Conference on Noise and Fluctuations, ICNF, 2003 – present.

5. TEXMEMS (Texas Area – Microelectromechanical Systems) Workshop Executive Board, 2000 - present.
6. IEEE-Electron Devices Society Distinguished Lecturer

2001-present Chairman, IEEE Electron Devices Society Dallas Section, arranged several speaker series for EDS Dallas members.

1998-present Member, IEEE Electron Devices Society, National Membership Committee

December 12 – 15, 2004: Attended IEEE-Electron Devices Society, Administrative Committee Meeting, presented chapter activities at the Sections and Regions Meeting. San Francisco CA.

November 11-12, 2004: Attended SPRING II Conference, Presented Smart Skin, UTD.

November 3 – 5, 2004: Attended SEMATECH Conf. on Characterization of High-k Gate Stacks. (Invitation only)

Organized and find funding for NEMS Distinguished Speaker Series: (NanoFab and IEEE-Electron Devices Society – Dallas Chapter):

1. **Infrared Imaging without Cryogenic Cooling**, Charles M. Hanson, Ph.D., Principal Fellow, Director of Technology and Strategy, Raytheon Commercial IR, November 2, 2004
2. **The Realities of System-on-Chip Integration,** Hans Stork, Ph.D., Senior Vice President and Chief Technology Officer, Texas Instruments Incorporated, November 11, 2004
3. **Microsystems and Nanosystems: Manufacturing Challenges and Opportunities,** Rajendra Singh, Ph.D., Prof. of Electrical and Computer Engineering, Clemson University, November 16, 2004
4. **Finding Applications for Organic Transistors**, Ananth Dodabalapur, Ph.D., Prof. of Electrical and Computer Engineering , The University of Texas at Austin, November 18, 2004.
5. **A Personal Perspective of Past History and Future Challenges,** Robert Biard, Ph.D., Consultant, Honeywell/Adopco, April 12, 2005
6. **Electric and Magnetic Field-Gradient Induced Separation Techniques for Microfluidic Biodetection Applications,** Conrad D. James, Ph.D., Senior Member of Technical Staff, Sandia National Laboratories, April 14, 2005
7. **RF MEMS: A Revolutionary Technology at Microwave Frequencies**, Brandon Pillans, Technical Lead of RF MEMS, Raytheon Advanced Products Center, April 21, 2005
8. **Advances in Photonic Devices for Analog Fiber Link Applications**, Paul K. L. Yu, Ph.D., Professor & Chair, Department of Electrical and Computer Engineering, University of California at San Diego, April 26, 2005

Metroplex Research Consortium for Electronic Devices and Materials (MRCEDM) was formed in 1999 around an extensive equipment donation from Texas Instruments, MRCEDM enlist academic scientists, engineers, staff, students, and the combined research capabilities of the universities of the North Central Texas region to catalyze industrial innovation and competitiveness. It currently includes of The University of Texas at Arlington, Southern Methodist University, Texas Christian University and The University of North Texas. Both Drs. Zeynep Celik-Butler and Donald Butler serve in the steering committee, which is the main operating committee of the consortium. Facilities provided by the member Universities were used for some of the material characterization and imaging needs of this project.

Contributions beyond science and engineering:

Donald Butler participated in the Advanced Summer Institute for Educators, organized by UTA and the DFW Semiconductor Executive Council. This was a weeklong program for 30 – 50 high school math and science teachers from the DFW metroplex. This program provides presentations and hands-on experience on cutting edge technology. This year's program featured a presentation on "Uncooled Infrared Detection", which included the work sponsored by this research grant. The goal is to provide teachers with an experience they can take back to their high schools and build into their curricula. Donald Butler also participated in an Upward Bound activity to talk to high

school seniors and juniors about electrical engineering as a career choice and the entrance requirements for typical engineering schools. Zeynep Celik-Butler gave two presentations to 5th graders on Nanotechnology at OC Taylor Elementary in Grapevine Colleyville Independent School District, April 2005.

b. Consultative and advisory functions to other laboratories and agencies, especially Air Force and other DoD laboratories. Provide factual information about the subject matter, institutions, locations, dates, and name(s) of principal individuals involved.

-none

c. Transitions. Describe cases where knowledge resulting from your effort is used, or will be used, in a technology application. Transitions can be to entities in the DoD, other federal agencies, or industry. Briefly list the enabling research, the laboratory or company, and an individual in that organization who made use of your research.

-none

8. New Discoveries

-none to date

9. Honors and Awards

-none this reporting period